(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 110 563 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.06.2001 Bulletin 2001/26

(51) Int Cl.[7]: **A61M 1/16**, B01D 69/00

(21) Application number: **00311580.5**

(22) Date of filing: **21.12.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **21.12.1999 JP 36296099**
21.12.1999 JP 36296199
21.12.1999 JP 36296299

(71) Applicant: **TORAY INDUSTRIES, INC.**
Tokyo 103-8666 (JP)

(72) Inventors:
- **Kozawa, Hidetoshi, Cosmos Higashiyama 605**
  Higashiyama-ku, Kyoto-shi, Kyoto605-0874 (JP)
- **Nakashima, Hidekazu**
  Yasu-gun, Shiga 520-2413 (JP)
- **Wada, Shigehisa**
  Otsu-shi, Shiga 520-0842 (JP)

(74) Representative: **Coleiro, Raymond et al**
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

(54) Dialyzers for blood treatment and processes for production thereof

(57) A dialyzer for blood treatment has incorporated therein a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the water permeating performance of the semipermeable membrane after drying being 1/2 or higher relative to that before drying and the dialyzer satisfying any one of the following requirements; (A) the vitamin B12 clearance is not smaller than 135 ml/min per 1.6 m^2; and (B) the amount of the hydrophilic polymer that is eluted from the semipermeable membrane is not higher than 10 ppm.

A dialyzer having incorporated therein a semipermeable membrane, which comprises a hydrophobic polymer and a hydrophilic polymer, can be produced by a process comprising: drying the semipermeable membrane; and saturating the dried semipermeable membrane with a water ratio of not smaller than 100% based on the dry weight of the semipermeable membrane, providing an inert gas atmosphere inside the dialyzer, and then irradiating the semipermeable membrane with gamma-rays in the inert gas atmosphere.

In a process for producing a hollow fiber membrane for use in blood treatment through dry/wet spinning from a stock solution comprising 15 to 18% by weight of a hydrophobic polymer and 4 to 8% by weight of a hydrophilic polymer, the dry zone is filled with dry mist.

EP 1 110 563 A2

Description

[0001] The present invention relates to a semipermeable membrane for blood treatment which exhibits little change in performance upon drying and reduced elution of a hydrophilic polymer therefrom; a dialyzer for use in blood treatment using the same; and a processes for producing a dialyzer having incorporated therein a semipermeable membrane which exhibits little change in performance before and after drying and reduced elution of a hydrophilic polymer therefrom.

[0002] As a material for a semipermeable membrane for blood treatment such as an artificial kidney, there have been used a number of materials. For example as a natural material, cellulose and its derivatives, e.g. cellulose diacetate and cellulose triacetate, were originally used, and synthetic polymers were then developed, such as polysulfone, polymethyl methacrylate (PMMA) and polyacrylonitrile. Recently, modified cellulose membranes have also been used which are prepared by treating cellulose with polyethylene glycol (PEG) or the like to modify their compatability with blood. In semipermeable membranes for blood treatment in patients suffering from chronic renal failure, attempts have been made to reduce the leakage of albumin to a minimum while positively removing low molecular proteins other than albumin. In addition to such improvement in the membranes, hemodiafiltration (HDF) procedures and push-and-pull procedures have been developed for increasing the dialysis efficiency and positive removal of undesirable low molecular weight proteins. Polysulfone, which has a high water permeability, is now widely used since it meets the above-mentioned requirements. In a polysulfone membrane, a hydrophilic polymer is generally blended to impart an affinity for blood to the membrane. However, the polysulfone membrane has a defect in that once it is dried the properties tend to be changed to a great extent. Hence, it is difficult to produce a dry type of polysulfone membrane dialyzer which is light-weight and easy to handle.

[0003] Accordingly, we have addressed the problem of providing a dialyzer having a dry or semi-dry type of semipermeable membrane which has advantages such as being light-weight and resistant to freezing, wherein the semipermeable membrane is improved in water permeability and dialysis performance (which are poor in a dialyzer having a conventional dry or semi-dry type membrane) to the same level as those of a dialyzer having a wet type membrane.

[0004] We have also addressed the problem of providing a dry or semi-dry type of dialyzer membrane having not only the above advantages but which also exhibits a reduced elution of a hydrophilic polymer therefrom.

[0005] We have found surprisingly that such advantages may be achieved by the following respective aspects of the invention.

[0006] Thus, according to one aspect of the present invention, there is provided a dialyzer for blood treatment having incorporated therein a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the water permeating performance of the semipermeable membrane after drying being 1/2 or higher relative to that before drying and the dialyzer satisfying any of the following requirements.

(A) the vitamin B12 clearance is not smaller than 135 ml/min per 1.6 m^2; and
(B) the amount of the hydrophilic polymer that is eluted from the semipermeable membrane is not higher than 10 ppm.

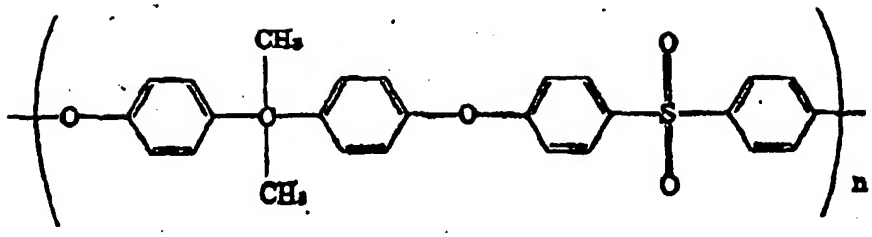
[0007] According to another aspect of the present invention, there is provided a process for producing a dialyzer having incorporated therein a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the process comprising:

drying the semipermeable membrane; and
saturating the dried semipermeable membrane with a water ratio of not smaller than 100% based on the dry weight of the semipermeable membrane [i.e. (weight of water alone/dry weight of semipermeable membrane alone) x 100%], providing an inert gas atmosphere to the inside of the dialyzer, and then irradiating the semipermeable membrane with gamma-ray in the inert gas atmosphere.

According to yet another aspect of the present invention, there is provided a process for producing a hollow fiber membrane for use in blood treatment through dry/wet spinning from a spinning solution comprising 15 to 18% by weight of a hydrophobic polymer and 4 to 8% by weight of a hydrophilic polymer, in which the dry zone is filled with dry mist.

[0008] Preferred embodiments of the invention will now be described.

[0009] In a dialyzer embodying the present invention, the hydrophobic polymer which may be used in the semipermeable membrane includes a number of engineering plastics, such as polysulfone, polyamide, polyimide, polyphenyl ether and polyphenylene sulfide. Preferably, the hydrophobic polymer is polysulfone represented by the formula below, which shows the skeleton of the polysulfone. Polysulfone derivatives in which the benzene ring in the skeleton is modified are also useful in a dialyzer embodying the present invention.



[0010] The hydrophilic polymer which may be used in the semipermeable membrane includes, for example, polyethylene glycol, polyvinyl alcohol, carboxymethyl cellulose and polyvinyl pyrrolidone, which may be used alone or in combination. Polyvinyl pyrrolidone (hereinafter, sometimes referred to as "PVP") is preferred since it is relatively high in industrial availability. It is preferable to use two or more of hydrophilic polymers having different molecular weights. In this instance, the hydrophilic polymers preferably have different weight average molecular weights from one another by five times or more.

[0011] The spinning solution to be used for the preparation of the semipermeable membrane preferably comprises a hydrophobic polymer, a hydrophilic polymer, a solvent and an additive. The solvent may be an amphiprotic solvent which can fully dissolve all of the hydrophobic polymer, the hydrophilie polymer and the additive. Specific examples of the solvent include dimethylacetamide, dimethylformamide, dimethylsulfoxide, acetone, acetaldehyde and 2-methyl pyrrolidone. Dimethylacetamide is particularly preferred from the viewpoints of safety, stability and toxicity. The additive may be one which is a poor solvent for the hydrophobic polymer but is miscible with the hydrophilic polymer, such as an alcohol, glycerin, water and an ester. Water is particularly preferred from the viewpoint of process suitability.

[0012] The viscosity of the spinning solution for membrane production may depend on the molecular weight of the hydrophilic polymer, since commercially available hydrophilic polymers have low molecular weights. A decreased viscosity of the spinning solution could cause breakage or swinging of fibers during the preparation of a hollow fiber membrane, leading to a decreased stability of the resulting hollow fiber membrane. Accordingly, when PVP is used as the hydrophilic polymer, PVP with a high molecular weight is preferred. When two or more types of PVP are used in a mixture, the PVP mixture preferably has an average molecular weight of 200,000 or higher.

[0013] Next, the respective components of the hydrophobic and hydrophilic polymers in the spinning solution are given. As stated above, as the polymer content increases, a membrane can be formed more effectively but the porosity of the resulting membrane decreases, leading to a decreased water permeability. Accordingly, there is an optimum range for the polymer content. To obtain a membrane that can exert both a high permselectivity and a low albumin permeability even when dried, as in a membrane embodying the present invention, the concentration of the hydrophobic polymer is prefarably 10 to 20% by weight, more preferably 12 to 18% by weight, and the coneentration of the hydrophilic polymer is preferably 2 to 20% by weight, more preferably 3 to 15% by weight In the case where two or more hydrophilic polymers having different molecular weights are used, it is preferable that the content of hydrophilic polymers having molecular weights of 100,000 or higher in the spinning solution is 1 to 10% by weight. If this content is too large, the viscosity of the spinning solution increases, which may cause difficulty in formation of a membrane, as well as decrease in water permeability and diffusion performance. On the contrary, if this content is too small, it becomes impossible to construct a desirable network structure desired for the permeation of medium-to-high molecular weight uremia-toxic proteins.

[0014] A process embodying the invention for preparing the semipermeable membrane is described hereinbelow. A spinning solution having a composition as mentioned above, along with a core solution, is extruded from a spinneret through an annular double slit tube to form a hollow fiber membrane. The membrane is washed with water, dried, and then crimped. The crimped membrane is taken up and cut to an appropriate length. The cut membranes are placed in a module case, in which both end faces of the bundle of the membranes are sealed with a potting material. In this manner, a hollow fiber membrane module is produced.

[0015] Preferably, in accordance with a process aspect of the invention, the membrane is formed by a dry/wet spinning process, in which a dry zone is filled with dry mist. The dry mist refers to a mist-like material comprising water particles of 10 μm or smaller. The introduction of the dry mist into the dry zone can generate cores which may play an important role in the process for forming an outer surface of the hollow fiber membrane. PVP can coagulate around the cores to form PVP phases; thus, phase separation occurs in the dry zone. Subsequently, the fully grown PVP phases are removed in the coagulation bath, generating large pores. A conventional polysulfone dialyzing membrane generally has an asymmetric structure, where the permeation of material is controlled only through the inner surface. However, by providing such large pores on the outer surface of the membrane, an outer support layer having a coarse, porous structure can be formed. This structure enables a substance to be transferred through the membrane by diffusion more readily, thus providing an increased permeation performance to the finished dialyzing membrane.

[0016] Preferably, in accordance with another process aspect of the present invention, for the formation of the hollow fiber membrane (not "module"), a conventional process including the treatment of the hollow fiber membrane with a moisture-retaining agent but not including any drying of the membrane is not employed and, instead, a process including the positive drying of the membrane is employed. As a result, a hollow fiber membrane of which the water permeating performance after drying is 1/2 or higher relative to that before drying can be produced. Preferably, it should be 75% or higher, and more preferably it should be 90% or higher. Since, in a process embodying the present invention, the membrane is dried without the treatment with a moisture-retaining agent, the spinning solution should be designed taking the shrinking of the dried membrane into consideration. When the semipermeable membrane is used in this state, particularly in an artificial kidney, however, a considerable amount of the hydrophilic polymer may diffuse from the membrane. For the purpose of reducing such elution, it is preferable that the membrane be subjected to a cross-linking treatment with gamma-ray irradiation, electron beam irradiation, or heat or chemical treatment. If gamma-ray is irradiated in the presence of air (i.e., oxygen), the breakage of the backbone of the hydrophilic polymer could occur by the action of excited oxygen radicals, resulting in the decomposition of the polymer. To solve this problem, it is preferable to saturate the membrane with a water ratio of not smaller than 100% and not higher than 1000%, more preferably 100 to 600%, still more preferably 100 to 400% based on the dry weight of the membrane, replace the atmospheric air with an inert gas, and then irradiate the membrane with gamma-rays. Thus, elution of the hydrophilic polymer from the membrane can be prevented effectively. As the inert gas, nitrogen, argon, helium, and carbon dioxide are preferably used. Nitrogen, which is inexpensive, is particularly preferred. The exposure dose of gamma-rays is preferably 10 to 50 KGy, more preferably 10 to 30 KGy. Since the cross-linking treatment induces the binding between the hydrophobic polymer and the hydrophilic polymer, elution of the hydrophilic polymer from the membrane can be reduced. The forced elution test of the membrane as described below demonstrated that no peak indicating the presence of the hydrophilic polymer eluted from the membrane was observed. Accordingly, a semipermeable membrane having an elution amount of not higher than 10 ppm can be manufactured. The term "an elution amount" refers to the amount of the hydrophilic polymer in an extract that is prepared by dispersing or dissolving a certain amount of hollow fibers into a solvent which is a good solvent for both the hydrophobic and the hydrophilic polymers, in that both polymers have a solubility therein of not less than 0.5 g/ml and the solvent is immiscible with water, and then extracting the hydrophilic polymer from the solution with a certain amount of aqueous phase (0.1N ammonium chloride solution, pH 9.5) to give the extract. In the case where the hydrophilic polymer is a mixture of polysulfone and polyvinyl pyrrolidone, the good solvent is preferably methylene chloride.

[0017] The semipermeable membrane prepared as mentioned above characteristically exhibits good performance as a membrane for blood treatment, such as good diffusing capacity for uremia-causing substances and diffusion resistance against albumin, which is a useful protein, and has a reduced elution of the hydrophilic polymer therefrom, due to the network structure formed with the hydrophobic and hydrophilic polymers. If the albumin permeability exceeds 3%, physical conditions of hypoalbuminemia patients or the nutritive conditions of elderly persons may affected. Therefore, the albumin permeability is preferably 3% or lower. The uremia-causing substance or uremic toxin may be urea, creatinine or uric acid. As the indicator of the substance permeation, that of vitamin B12 may be adopted. In the semipermeable membrane of the present invention, the vitamin B12 clearance is preferably 135 ml/min or higher per 1.6 m^2. The clearance of urea, creatinine and uric acid is preferably 188, 175 and 165 ml/min, respectively, or higher per 1.6 m^2 from a practical viewpoint.

[0018] In order to achieve the above-stated properties, the content of the hydrophilic polymer in the membrane after the cross-linking is preferably 2 to 6% by weight. Too small a content may cause reduction in wetting ability against water and coagulation may occur upon contacting with blood. It is also preferable that the membrane after the cross-linking contain insoluble substances in a concentration of 5 to 15% by weight.

As stated above, a semipermeable membrane for blood treatment embodying the present invention exhibits a water permeability after drying of 1/2 or higher relative to that before drying, and this can be achieved by employing a step of drying the membrane in the state where no moisture-retaining agent is attached to the membrane and a step of cross-linking the dried membrane after moisture conditioning (i.e., saturating with water). As a result, the membrane can be applied to a dialyzer which exhibits good properties such as decreased water permeability and less leaking of substances eluted from the membrane even when used after drying. The membrane of the present invention can be used in a dry or semi-dry state (as used herein, the term "semi-dry state" refers to a state where water is present in the membrane but spaces between the hollow fibers are filled with a gas). Accordingly, a semipermeable membrane can be provided which is light-weight, almost free from the problem of freezing, is easy to handle and has excellent performance. The production of such a semipermeable membrane may contribute to the reduced cost of the dialysis. Moreover, the membrane can exhibits a high dialysis performance at various temperatures and sterilization conditions since degradation in dialysis performance by drying hardly occurs. On the other hand, in the application to the treatment of a human body, elution of the hydrophilic polymer (a substance foreign to the body) can be reduced, leading to increased safety of the membrane as medical equipment. The dialyzer according to the present invention is applicable to medical apparatuses for blood treatment, such as an artificial kidney, a plasma separative membrane and a carrier

for extracorporeal circulation adsorptive separation.

[0019] Specific embodiments of the invention will now be described in more detail with reference to the following working Examples. The determination methods employed are as follows.

(1) Determination of water permeability

[0020] A hydraulic pressure of 100 mmHg is applied to the inside of each hollow fiber in a glass tube mini-module (comprising 36 of hollow fibers; effective length 10 cm) in which both ends of the hollow fiber bundle are sealed), and then the amount of the permeate coming out of the mini-module per unit time period is measured.

[0021] The water permeation performance is calculated in accordance with the following equation:

$$UFR(ml / hr / m^2 / mmHg) = \frac{Q_w}{P \times T \times A}$$

wherein Qw is the amount of the filtrate (ml); T is the efflux time (hr); P is the pressure (mmHg); and A is the area of the membrane (m^2) (in terms of the area of the inner surface of the hollow fiber).

(2) Determination of change in performance upon drying

[0022] When no moisture-retaining agent is present in a hollow fiber to be tested, the fibers may be dried under the conditions below. However, when any moisture-retaining agent is present. 10 g of the hollow fiber is soaked in 150 ml of pure water and allowed to stand for 24 hours. This procedure is repeated twice and then dried in the form of a fiber bundle at 100°C for 24 hours. The water permeability is determined before and after the drying.

(3) Determination of clearance of solutes

[0023] This determination is performed in accordance with the description of "the Performance Evaluation Criteria for Dialyzers" (the Japanese Society of Artificial Organs, ed., issued on September, 1982). In this publication, there are shown two determination methods for clearance. In this example, the clearance is determine in accordance with the TMP 0mmHg value. Among the solutes tested, vitamin B12 may. be decomposed by irradiation with light. Accordingly, it is preferred to determine the clearance of vitamin B 12 within the day of sampling, preferably immediately after the sampling. The clearance is determined at a rate of liquid fed to the module QB of 200 ml/min and a rate of flow of water through the dialyzate section of the module QD of 500 ml/min, using the equation below. When the areas of the membranes used for this test are different, the overall mass transfer coefficiency may be calculated based on the clearance value of each solute and the calculated value may be converted in area terms.

Clearance:

$$C_L(ml / min) = \frac{CBi - CBo}{CBi} = Q_B$$

wherein CB_I is the concentration at the module inlet; CB_0 is the concentration at the module outlet; and QB is the rate of liquid fed to the module (ml/min).

(4) Determination of albumin permeability

[0024] Bovine blood (treated with heparin) with a hematocrit value of 30% and a total protein content of 6.5 g/dl, which has been kept at a temperature of 37°C), in a blood tank is used. The bovine blood is fed to the inside of the hollow fibers through a pump at a rate of 200 ml/min. During this process, the pressure at the module outlet is adjusted to achieve a filtration rate of 20 ml/min per m^2 of the module area (which is equivalent to 32 ml/min per 1.6 m^2), and the filtrate and the blood from the outlet are fed back to the blood tank. One hour after the start of reflux, the blood at the inlet and the outlet of the module and the filtrate are sampled. The blood samples are centrifuged to separate the serum. The serum is analyzed using the BCG (bromcresol green) method kit of A/G B-Test Wako (a tradename, Wako Pure Chemical Industries, Ltd.), and the albumin permeability (%) of the individual samples is calculated from the serum concentrations. For the determination of albumin concentration in the filtrate at high sensitivity, a calibration curve for albumin at low concentrations is established by making appropriate dilutions of serum albumin included in the kit.

$$\text{Albumin permeability (\%)} = \frac{2 \times C_F}{(CBi + CBo)} \times 100$$

wherein C_F, CB_i and CB_0 are concentrations of albumin in the filtrate, at the module inlet and at the module outlet, respectively.

(5) Determination of concentration of a hydrophilic polymer PVP transferred into the aqueous layer in forced elution test

[0025] One liter of pure water is passed through the dialyzing module from the blood side to the dialyzate side to wash the module. 1 g of the hollow fiber from the module is dissolved in 10 ml of methylene chloride (10 % w/v). The solution is extracted with 10 ml of 0.1N ammonium chloride solution (pH 9.5), and the resulting methylene chloride aqueous solution is supercentrifuged (20,000 rpm x 15 min). The aqueous layer is passed through a filter (pore size: 0.5 μm) to obtain a sample solution.

[0026] Analysis of the sample solution is performed at 23°C using two serially connected Toso TSK-gel-GMPWXL columns with a theoretical number of steps (8,900x2) under the following conditions: mobile phase - 0.1N ammonium chloride solution (pH 9.5); flow rate -1.0 ml/min; sample loading - 0.2 ml. Nine monodisperse polyethylene glycol products are used as the standard materials for calibration of molecular weight and a peak area-concentration calibration curve for a reference PVP product is established. The concentration of PVP transferred into the aqueous layer (5 ml) is determined from the PVP peak area of each sample solution. Samples containing a detectable amount of PVP are determined on the recovery of PVP (i.e., transfer rate into the aqueous layer) from that of the reference, and the amount of PVP eluted into the aqueous layer is calculated from the PVP concentration in the aqueous layer based on the recovery.

(6) Determination of PVP content by elemental analysis

[0027] A sample irradiated with gamma-rays is dried at ordinary temperature using a vacuum pump. 10 mg of the dried sample is analyzed using a CHN elemental analyser. The PVP content is calculated from the nitrogen content.

(7) Determination of insoluble material content

[0028] 10 g of a hollow fiber irradiated with gamma-ray is dissolved in 100 ml of dimethylformamide. The solution is centrifuged at 1,500 rpm for 10 min to separate insoluble materials, and the supernatant is discarded. This procedure is repeated tie times. The insoluble material is washed with 100 ml of pure water, and then centrifuged three times as mentioned above. The resulting solid material is evaporated to dryness and then dried with a vacuum pump. The weight of the dried solid material is used to calculate the content of insoluble material.

Example 1

[0029] Four pans of polysulfone (Amoco, Udel-P3500), 12 parts of polysulfone (Amoco, Udel-P1700), 4 parts of polyvinyl pyrrolidone (International Special Products, hereinafter, referred to as "ISP"; K30) and 2 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation.

[0030] The viscosity of the spinning solution was 13.4 Pa·s at 50°C. The spinning solution was introduced to a spinneret at 50°C, and extruded, along with a core solution comprising 65 parts of dimethylacetamide and 35 parts of water, from the spinneret through an annular double slit tube having an outside diameter of 0.35 mm and an inside diameter of 0.25 mm, whereby a hollow fiber membrane was formed. The membrane was subjected to moisture conditioning at 30°C and a dew point of 28°C The conditioned membrane was passed through a dry zone atmosphere which had a length of 250 mm and contained dry mist particles of 10 μm or smaller, then through a coagulation bath at 40°C comprising 20 wt% of dimethylacetamide and 80 wt% of water. The resulting membrane was subjected to a washing step with water at 80°C for 60 sec, a drying process at 135°C for 2 min, and then a crimping step at 160°C. The resulting membrane was taken up into a bundle. The hollow fiber membrane bundle was packaged in a module case so that the area of the hollow fiber membrane became 1.6 m^2, and potted. The potted bundle was provided with opening faces at the both ends to form a dialyzing module. Thereafter, the blood side was filled with deaerated warmed water (37°C) at a feed rate of 200 ml/min for 1 min and then, an inert gas (nitrogen) was fed to the module at a pressure of 0.1 MPa for 15 sec to force out the filling water therefrom. By this procedure, the dialyzate side was also replaced with the inert gas. In this state, the water content in the hollow fiber membrane was 320%.

[0031] The module was irradiated with gamma-rays (25 KGy) in a state where the membrane was wet and the module

had been filled with the inert gas. Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was demonstrated that the module had a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 195 ml/min, 185 ml/min, 180 ml/min, 186 ml/min and 145 ml/min, respectively, a water permeation performance of 756 ml/hr/m^2/mmHg, and an albumin permeability of 1.5%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 772 ml/hr/m^2/mmHg, and no degradation in performance was observed. The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 3.5%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 7.2%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, no peak was detected and therefore PVP was not detected.

Example 2

[0032] Four parts of polysulfone (Amoco, Udel-P3500), 12 parts of polysulfone (Amoco, Udel-P1700), 3 parts of polyvinyl pyrrolidone (ISP, K30) and 3 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 18 Pa's at 50°C. A module was fabricated in the same manner as in Example 1. The water content in the hollow fiber membrane after forcing out water from the membrane was 330%. The dialyzate side was also replaced with the inert gas. The module was irradiated with gamma-rays (25 KGy) in a state where the membrane was wet and the module had been filled with the inert gas. Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was shown that the module had a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 193 ml/min, 182 ml/min, 178 ml/min, 184 ml/min and 142 ml/min, respectively, a water permeation performance of 720 ml/hr/m^2/mmHg, and an albumin permeability of 1.8%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 734 ml/hr/m^2/mmHg, and no degradation in performance was observed.

[0033] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 4.0%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 7.8%. When the forced clution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1.

Example 3

[0034] Four parts of polysulfone (Amoco, Udel-P3500), 12 parts of polysulfone (Amoco, Udel-P1700), 2 parts of polyvinyl pyrrolidone (ISP, K30) and 4 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 23 Pa's at 50°C. A module was fabricated in the same manner as in Example 1.

[0035] The water content in the hollow fiber membrane after forcing out Water from the membrane was 400%. The dialyzate side was also replaced with the inert gas. The module was irradiated with gamma-rays (25 KGy) in a state where the membrane was wet and the module had been filled with inert gas. Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was shown that the module had a water permeation performance of 702 ml/hr/m^2/mmHg, a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 191 ml/min, 180 ml/min, 175 ml/min, 181 ml/min and 140 ml/min, respectively, and an albumin permeability of 1.0%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 727 ml/hr/m^2/mmHg, and no degradation in performance was observed.

[0036] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 4.7%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 8.3%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1,

Example 4

[0037] Four parts of polysulfone (Amoco, Udel-P3500), 12 parts of polysulfone (Amoco, Udel-P1700), 1 part of polyvinyl pyrrolidone (ISP, K30) and 5 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 29 Pa's at 50°C. A module was fabricated in the same manner as in Example 1.

[0038] The water content in the hollow fiber membrane after forcing out water from the membrane was 380%. The dialyzate side was also replaced with the inert gas. The module was irradiated with gamma-rays (25 KGy) in a state where the membrane was wet and the module had been filled with inert gas. Determination of water permeation per-

formance, clearance of each solute and albumin permeability was performed. As a result, it was shown that the module had a water permeation performance of 675 ml/hr/m^2/mmHg, a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 190 ml/min, 179 ml/min, 173 ml/min, 179 ml/min and 138 ml/min, respectively, and an albumin permeability of 0.9%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 668 ml/hr/m^2/mmHg, and no degradation in performance was observed.

[0039] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 5.1%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 8.9%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1.

Example 5

[0040] Four parts of polysulfone (Amoco, Udel-P3500), 12 parts of polysulfone (Amoco, Udel-P1700) and 6 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 38 Pa·s at 50°C. A module was fabricated in the same manner as in Example 1.

[0041] The water content in the hollow fiber membrane after forcing out water from the membrane was 350%. The dialyzate side was also replaced with the inert gas. The module was irradiated with gamma-rays (25 KGy) in a state where the membrane was wet and the module had been filled with inert gas. Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was shown that the module had a water permeation performance of 620 ml/hr/m^2/mmHg, a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 189 ml/min, 177 ml/min, 169 ml/min, 178 ml/min and 137 ml/min, respectively, and an albumin permeability of 0.8%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 656 ml/hr/m^2/mmHg, and no degradation in performance was observed.

[0042] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 5.5%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 9.2%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1.

Example 6

[0043] Sixteen parts of polysulfone (Amoco, Udel-P3500), 4 parts of polyvinyl pyrrolidone (ISP, K30), and 2 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 14.0 Pa's at 50°C. A module was fabricated in the same manner as in Example 1.

[0044] The water content in the hollow fiber membrane after forcing out water from the membrane was 260%. The dialyzate side was also replaced with the inert gas. The module was irradiated with gamma-rays (25 KGy) in a state where the membrane was wet and the module had been filled with inert gas. Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was shown that the module had a water permeation performance of 350 ml/hr/m^2/mmHg, a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 195 ml/min, 185 ml/min, 180 ml/min, 187 ml/min and 145 ml/min, respectively, and an albumin permeability of 0.5%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 330 ml/hr/m^2/mmHg, and no degradation in performance was observed.

[0045] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 3.1%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 7.5%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1.

Comparative Example 1

[0046] Eighteen parts of polysulfone (Amoco, Udel-P3500), 6 parts of polyvinyl pyrrolidone (BASF, K30) and 3 parts of polyvinyl pyrrolidone (BASF, K90) were dissolved in 72 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 70 Pa's at 50°C. The spinning solution was introduced to a spinneret at 50°C, and extruded, along with a core solution comprising 65 parts of dimethylacetamide and 35 parts of water, from the spinneret through an annular double slit tube having an outside diameter of 0.35 mm and an inside diameter of 0.25 mm, whereby a hollow fiber membrane was formed. The membrane was subjected to moisture conditioning at 30°C and a dew point of 28°C. The conditioned membrane was passed through a dry zone which had a length of 250 mm, then through a coagulation bath at 40°C comprising 20 wt% of

dimethylacetamide and 80 wt% of water. The resulting membrane was subjected to a washing step with water at 80°C for 20 sec, and then a moisture conditioning step with a glycerin solution. After taking off the glycerin solution, the resulting membrane was packaged in a module case, and then potted. The potted bundle was provided with opening faces at both ends to form a dialyzing module. Thereafter, the module was washed to remove free glycerin therefrom, filled with water, and then irradiated with gamma-rays (25 KGy). Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was demonstrated that the module had a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 194 ml/min, 185 ml/min, 176 ml/min, 183 ml/min and 135 ml/min, respectively, a water permeation performance of 716 ml/hr/m^2/mmHg, and an albumin permeability of 0.7%

[0047] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 4.5%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 8.0%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1. Next, the liquid filled in the module was removed. After drying the membrane with a drier, the determination of the water permeation performance, clearance of each solute and albumin permeability was performed again. As a result, it was demonstrated that the module had a clearance of urea. creatinine, uric acid, phosphoric acid and VB12 of 186 ml/min, 177 ml/min, 169 ml/min, 176 ml/min and 119 ml/min, respectively, a water permeability of 0%, a water permeation performance of 10 ml/hr/m^2/mmHg, and an albumin permeability of 0.1%. Thus, the membrane showed remarkable degradation in performance after drying. When a portion of the hollow fiber before drying was taken out of the module and dried in the same manner as described above, similar degradation in performance was also observed.

Comparative Example 2

[0048] Seventeen parts of polysulfone (Amoco, Udel-P3500), 5 parts of polyvinyl pyrrolidone (BASF, K30) and 4 parts of polyvinyl pyrrolidone (BASF, K90) were dissolved in 73 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 40 Pa's at 50°C. A module was fabricated in the same manner as in Comparative Example 1. The module was irradiated with gamma-rays in a state where the module had been filled with water. Determination of water permeation performance, clearance of each solute and albumin permeability of the module was performed. As a result, it was demonstrated that the module had a clearance of ures, creatinine, uric acid, phosphoric acid and VB12 of 195 ml/min, 186 ml/min, 177 ml/min, 184 ml/min and 137 ml/min, respectively, and a water permeation performance of 600 ml/hr/m^2/mmHg, and an albumin permeability of 1.2%.

[0049] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 4.8%. The insoluble material content in the hollow fiber was determined and found to be 10.0%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1. Next, the liquid filled in the module was removed. After drying the membrane with a drier, the determination of the water permeation performance, clearance of each solute and albumin permeability was performed again. As a result, it was demonstrated that the module had a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 189 ml/min, 179 ml/min, 172 ml/min, 178 ml/min and 126 ml/min, respectively, a water permeability of 0%, a water permeation performance of 200 ml/hr/m2/mmHg, and an albumin permeability of 0.2%. Thus, the membrane showed remarkable degradation in performance after drying. When a portion of the hollow fiber before drying was taken out of the module and dried in the same manner as described above, similar degradation in performance was also observed.

Comparative Example 3

[0050] Seventeen parts of polysulfone (Amoco, Udel-P3500), 5 parts of polyvinyl pyrrolidone (BASF, K30) and 3 parts of polyvinyl pyrrolidone (BASF, K90) were dissolved in 74 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 33 Pa's at 50°C. A module was fabricated in the same manner as in Comparative Example 1. The module was irradiated with gamma-rays in a state where the module had been filled with water. Determination of water permeation performance, clearance of each solnte and albumin permeability was performed. As a result, it was demonstrated that the modnle had a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 196 ml/min, 187 ml/min, 178 ml/min, 185 ml/min and 138 ml/min, respectively, a water permeation performance of 525 ml/hr/m^2/mmHg, and an albumin permeability of 0.8%.

[0051] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 4.0%. The insoluble material content in the hollow fiber was determined and found to be 93%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous

layer, PVP was not detected, as in the case of Example 1. Next, the liquid filled in the module was removed. After drying the membrane with a drier, the determination of the water permeation performance, clearance of each solute and albumin permeability was performed again. As a result, it was demonstrated that the module had a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 191 ml/min, 181 ml/min, 173 ml/min, 180 ml/min and 126 ml/min, respectively, a water permeability of 0%, a water permeation performance of 340 ml/hr/m^2/mmHg, and an albumin permeability of 0.5%. Thus, the membrane showed remarkable degradation in performance after drying, When a portion of the hollow fiber before drying was taken out of the module and dried in the same manner as described above, similar degradation in performance was also observed.

Comparative Example 4

[0052] Sixteen parts of polysulfone (Amoco, Udel-P3500), 4 parts of polyvinyl pyrrolidone (ISP, K30) and 2 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 14.0 Pa's at 50°C. A module was fabricated in the same manner as in Example 1, except that the dry zone was not a dry mist atmosphere.

[0053] The water content in the hollow fiber membrane after forcing out water from the membrane was 230%. The dialyzate side was also replaced with the inert gas. The membrane was irradiated with gamma-rays (25 KGy) in a state where the membrane was wet and the module was filled with the inert gas. Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was shown that the module had a water permeation performance of 350 ml/hr/m^2/mmHg, a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 190 ml/min, 180 ml/min, 175 ml/min, 182 ml/min and 138 ml/min, respectively, and an albumin permeability of 0.6%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 340 ml/hr/m^2/mmHg, and no degradation in performance was observed.

[0054] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 3.3%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 7.8%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous layer, PVP was not detected, as in the case of Example 1.

Comparative Example 5

[0055] Sixteen parts of polysulfone (Amoco, Udel-P3500), 4 parts of polyvinyl pyrrolidone (ISP, K30) and 2 parts of polyvinyl pyrrolidone (ISP, K90) were dissolved in 77 parts of dimethylacetamide and 1 part of water with heating, to obtain a spinning solution for membrane formation. The viscosity of the spinning solution was 14.0 Pa's at 50°C. A module was fabricated in the same manner as in Example 1, except that the water with which the membrane was filled was forced out with compressed air and the atmosphere was not replaced with any inert gas. The water content in the hollow fiber membrane in this state was 260%. The membrane was irradiated with gamma-rays (25 KGy) in a state where the module was filled with air and the membrane was wet. Determination of water permeation performance, clearance of each solute and albumin permeability was performed. As a result, it was shown that the module had a water permeation performance of 350 ml/hr/m^2/mmHg, a clearance of urea, creatinine, uric acid, phosphoric acid and VB12 of 195 ml/min, 185 ml/min, 180 ml/min, 187 ml/min and 145 ml/min, respectively, and an albumin permeability of 0.5%. After drying, the water content in the membrane was 0%, the water permeation performance of the hollow fiber was 340 ml/hr/m^2/mmHg, and no degradation in performance was observed,

[0056] The PVP content in the hollow fiber membrane was determined by elemental analysis and found to be 3.1%. The insoluble material content in the hollow fiber after irradiation with gamma-rays was determined and found to be 7.8%. When the forced elution test was performed to determine the concentration of PVP transferred from the hollow fiber membrane into the aqueous llayer, however, 1255 ppm of PVP was detected in the aqueous layer.

[0057] Thus, embodiments of the present invention allow the provision of (1) a dialyzer for blood treatment which had incorporated therein a dry-type semipermeable membrane having less change in performance before and after drying and advantages such as being light-weight, free from the problem of freezing and having good water permeability and dialysis performance; (2) a dialyzer for blood treatment which is light-weight, easy to handle, and exhibits a reduced elution of a hydrophilic polymer; and (3) a process for producing a semipermeable membrane for blood treatment suitable for dialysers.

TABLE 1

	Examples						Comparative Examples				
	1	2	3	4	5	6	1	2	3	4	5
Water permeation performance after-dry/before-dry	772/736	734/720	727/702	668/675	656/620	360/330	10/716	200/600 ca. 1/3	340/525 ca. 2/3	350/340	350/340
PSF/PVP (K30/K90)	16(4/2)	16(3/3)	15(12/4)	16(1/5)	16(0/6)	16(4/2)	18/(6/3)	17/(5/4)	17/(5/3)	16(4/2)	16(4/2)
Dry zone	Dry mist						No mist				Dry mist
Filled gas	N_2										Air
Liquid content at γ-ray irradiation (%)	320	330	400	390	350	260	>1000	>1000	>1000	230	260
PVP content (%)	3.5	4.0	4.7	5.1	5.5	3.1	4.5	4.8	4.0	3.3	3.1
Albumin permeability (%)	1.5	1.8	1.0	0.9	0.8	0.5	0.1	0.2	0.5	0.6	0.5
Urea (pre/post) ml/min	195	193	191	190	189	195	194/188	193/189	196/191	190	195
Cr (pre/post)	185	182	180	179	177	185	183/177	186/179	187/181	180	185
Uralo acid (pre/post)	180	178	175	173	169	180	176/169	177/172	179/173	175	180
Phosphoric acid (pre/post)	186	184	181	179	178	187	183/176	184/178	185/180	182	187
Vitamin (pre/post)	145	142	140	138	137	145	135/119	137/126	138/126	138	145
PVP elution (PPM)	0	0	0	0	0	0	0	0	0	0	1255
Insoluble material (%)	7.2	7.8	8.3	8.9	9.2	7.5	8.0	10.0	9.3	7.8	7.8

Claims

1. A dialyzer for blood treatment having incorporated therein a semipermeable membrane which comprises a hydro-

phobic polymer and a hydrophilic polymer, the water permeating performance of the semipermeable membrane after drying being 1/2 or higher relative to that before drying and the dialyzer satisfying any of the following requirements:

(A) the vitamin B12 clearance is not smaller than 135 ml/min per 1.6 m^2; and
(B) the amount of the hydrophilic polymer that is eluted from the semipermeable membrane is not higher than 10 ppm.

2. A dialyzer according to Claim 1, wherein the water permeating performance of the semipermeable membrane after drying is 75% or higher relative to that before drying.

3. A dialyzer according to Claim 2, wherein the water permeating performance of the semipermeable membrane after drying is 90% or higher relative to that before drying.

4. A dialyzer according to any preceding Claim, wherein the hydrophobic polymer is a polysulfonic resin and the hydrophilic polymer is polyvinyl pyrrolidone.

5. A dialyzer according to Claim 4, wherein the content of the polyvinyl pyrrolidone in the semipermeable membrane is 1 to 10% by weight based on the content of the polysulfonic resin.

6. A dialyzer according to any preceding Claim, wherein the albumin permeability is not higher than 3%.

7. A process for producing a dialyzer having incorporated therein a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the process comprising:

drying the semipermeable membrane; and
saturating the dried semipermeable membrane with water at a water ratio of not smaller than 100% based on the dry weight of the semipermeable membrane [i.e. (weight of water alone/dry weight of semipermeable membrane alone) x 100%], providing an inert gas atmosphere inside the dialyzer, and then irradiating the semipermeable membrane with gamma-rays in the inert gas atmosphere.

8. A process according to Claim 7, wherein the water ratio is not smaller than 100% and not higher than 600% based on the dry weight of semipermeable membrane.

9. A process according to Claim 7 or Claim 8, wherein the inert gas is nitrogen or carbon dioxide gas.

10. A process according to any one of Claims 7 to 9, wherein, in the step of drying, the water content in the semipermeable membrane is reduced to a level not higher than 5%.

11. A process according to Claim 10, wherein the water content is not higher than 2%.

12. A process for producing a hollow fiber membrane for use in blood treatment through dry/wet spinning from a stock solution comprising 15 to 18% by weight of a hydrophobic polymer and 4 to 8% by weight of a hydrophilic polymer, in which the dry zone is filled with dry mist.

13. A process according to Claim 12, wherein the hydrophobic polymer is a polysulfonic resin and the hydrophilic polymer is polyvinyl pyrrolidone.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 110 563 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
19.05.2004 Bulletin 2004/21

(43) Date of publication A2:
27.06.2001 Bulletin 2001/26

(21) Application number: **00311580.5**

(22) Date of filing: **21.12.2000**

(51) Int Cl.[7]: **B01D 69/02**, B01D 71/68, B01D 67/00, B01D 61/28, A61M 1/16

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **21.12.1999 JP 36296099**
21.12.1999 JP 36296199
21.12.1999 JP 36296299

(71) Applicant: **TORAY INDUSTRIES, INC.**
Tokyo 103-8666 (JP)

(72) Inventors:
- **Kozawa, Hidetoshi, Cosmos Higashiyama 605**
  Higashiyama-ku, Kyoto-shi, Kyoto605-0874 (JP)
- **Nakashima, Hidekazu**
  Yasu-gun, Shiga 520-2413 (JP)
- **Wada, Shigehisa**
  Otsu-shi, Shiga 520-0842 (JP)

(74) Representative: **Coleiro, Raymond et al**
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

(54) Dialyzers for blood treatment and processes for production thereof

(57) A dialyzer for blood treatment has incorporated therein a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the water permeating performance of the semipermeable membrane after drying being 1/2 or higher relative to that before drying and the dialyzer satisfying any one of the following requirements; (A) the vitamin B12 clearance is not smaller than 135 ml/min per 1.6 m^2; and (B) the amount of the hydrophilic polymer that is eluted from the semipermeable membrane is not higher than 10 ppm.

A dialyzer having incorporated therein a semipermeable membrane, which comprises a hydrophobic polymer and a hydrophilic polymer, can be produced by a process comprising: drying the semipermeable membrane; and saturating the dried semipermeable membrane with a water ratio of not smaller than 100% based on the dry weight of the semipermeable membrane, providing an inert gas atmosphere inside the dialyzer, and then irradiating the semipermeable membrane with gamma-rays in the inert gas atmosphere.

In a process for producing a hollow fiber membrane for use in blood treatment through dry/wet spinning from a stock solution comprising 15 to 18% by weight of a hydrophobic polymer and 4 to 8% by weight of a hydrophilic polymer, the dry zone is filled with dry mist.

EP 1 110 563 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 31 1580

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 4 906 375 A (HEILMANN KLAUS) 6 March 1990 (1990-03-06)	1-6	B01D69/02 B01D71/68
A	* column 3, line 61 - column 5, line 31 * * column 6, line 63 - column 7, line 18 * * column 9, line 41 - column 10, line 22; examples *	12	B01D67/00 B01D61/28 A61M1/16
X	WO 94/00222 A (MINNTECH CORP) 6 January 1994 (1994-01-06)	1-6	
A	* page 5, lines 2-23 * * page 14, lines 19,20 * * page 15, lines 30-33 * * page 23, lines 1-7; examples * * page 31, line 16 - page 33, line 24 *	12	
X	US 5 762 798 A (COSENTINO LOUIS C ET AL) 9 June 1998 (1998-06-09)	1-6	
A	* column 4, line 48 - column 6, line 16 * * column 7, lines 36,37 *	12	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B01D
A61M

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
Munich	25 November 2003	Semino, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number
EP 00 31 1580

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1 (first option)
2-6 (as dependent on the first option of claim 1), 12, 13

European Patent Office

LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 00 31 1580

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1(first option),2-6(as dependent on the first option of claim 1),12,13

A dialyzer for blood treatment having incorporated a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the water permeating performance of the semipermeable membrane after drying being 1/2 or higher relative to that before drying and the dialyzer having a vitamin B12 clearance not smaller than 135 ml/min per 1.6 m2.
A process for producing a hollow fiber membrane for use in blood treatment through dry/wet spinning from a stock solution comprising 15 to 18 % by weight of a hydrophobic polymer and 4 to 8 % of a hydrophilic polymer, in which the dry zone is filled with dry mist.

---

2. claims: 1(second option), 2-6(as dependent on the second option of claim 1),7-11

A dialyzer for blood treatment having incorporated a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the water permeating performance of the semipermeable membrane after drying being 1/2 or higher relative to that before drying and the amount of the hydrophilic polymer that is eluted from the semipermeable membrane being not higher than 10 ppm.
A process for producing a dialyzer having incorporated therein a semipermeable membrane which comprises a hydrophobic polymer and a hydrophilic polymer, the process comprising:
drying the semipermeable membrane; and

saturating the dried semipermeable membrane with water at a water ratio of not smaller than 100% based on the dry weight of the semipermeable membrane, providing an inert gas atmosphere inside the dialyzer, and then irradiating the semipermeable membrane with gamma-rays in the inert gas atmosphere.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 31 1580

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-11-2003

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4906375 A	06-03-1990	DE 3436331 A1	17-04-1986
WO 9400222 A	06-01-1994	AU 4279093 A	24-01-1994
		CA 2136006 A1	06-01-1994
		EP 0647156 A1	12-04-1995
		JP 2818975 B2	30-10-1998
		JP 7504615 T	25-05-1995
		US 5762798 A	09-06-1998
		WO 9400222 A1	06-01-1994
		US 5683584 A	04-11-1997
US 5762798 A	09-06-1998	AU 676448 B2	06-03-1997
		AU 4447396 A	23-05-1996
		AU 668268 B2	26-04-1996
		AU 5584294 A	26-04-1994
		CA 2143863 A1	14-04-1994
		EP 0663853 A1	26-07-1995
		FI 951646 A	06-04-1995
		HU 70894 A2	28-11-1995
		JP 2887527 B2	26-04-1999
		JP 7507494 T	24-08-1995
		NO 951343 A	07-04-1995
		PL 308302 A1	24-07-1995
		WO 9407594 A2	14-04-1994
		US RE36914 E	17-10-2000
		US 5605627 A	25-02-1997
		US 5683584 A	04-11-1997
		AT 132766 T	15-01-1996
		AU 658885 B2	04-05-1995
		AU 1767592 A	17-11-1992
		BR 9205869 A	01-03-1995
		CA 2106482 A1	13-10-1992
		DE 69207587 D1	22-02-1996
		DE 69207587 T2	23-05-1996
		EP 0579749 A1	26-01-1994
		ES 2085014 T3	16-05-1996
		JP 2941944 B2	30-08-1999
		JP 5507328 T	21-10-1993
		MX 9201654 A1	01-10-1992
		RU 2086296 C1	10-08-1997
		WO 9218224 A1	29-10-1992
		AU 4279093 A	24-01-1994
		CA 2136006 A1	06-01-1994
		EP 0647156 A1	12-04-1995
		JP 2818975 B2	30-10-1998
		JP 7504615 T	25-05-1995

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 31 1580

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-11-2003

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5762798 A		WO 9400222 A1	06-01-1994

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82